Sep.

TRANSACTIONS

OF THE

Glasgow Technical College Scientific Society.

FOUNDED 1892.

Vol. VII. Part 2. Session 1910-1911.

THE "FIXED STARS."

BY

Mr. JOHN D. McDOUGALL.

26th November, 1910.

GLASGOW TECHNICAL COLLEGE,

204 George Street, Glasgow.

The Glasgow Technical College Scientific Society.

The Society was founded in 1892 to promote the study and practice of Engineering and other branches of Applied Science.

The Membership consists of past and present students of the Glasgow Technical College or kindred institutions, together with such others as the Council may consider eligible.

Annual Subscription:—

Life Members, - -	Four Guineas.
Ordinary Members, -	7s. 6d.
Student Members, - -	5s. 0d.

Applications for Membership should be addressed to the Hon. Secretary; Correspondence regarding Transactions to the Editor.

Nineteenth Session, 1910-11.

Council.

President.

George Ness, Esq., M.I.Mech.E.

Vice-Presidents.

Joseph Menmuir, A.M.I.E.E.
John Y. Moyes, A.G.T.C.
David Carlaw.
Peter Stobie.

Honorary Joint Secretaries.

Jas. W. Campbell, M.Sc., Technical College, Glasgow.
W. D. Lawrence, 35 Melville Street, Pollokshields.

Honorary Treasurer.

John E. Irvine, 3 Holmhead Street, Glasgow.

Honorary Librarian and Editor.

Peter Stobie, 27 Underwood Street, Langside.

Committee.

James Ainslie.
A. W. Barclay.
James Brash.
R. M. Harrison Kidd.
D. Keachie.
Alex. Marshall.
J. D. McKenzie.
Norman Young.

TRANSACTIONS

OF THE

Glasgow Technical College Scientific Society.

FOUNDED 1892.

VOL. VII., PART 2, SESSION 1910-1911.

(Paper read before an Ordinary Meeting of the Society, held in the Glasgow Technical College, 26th Nov., 1910; JOSEPH MENMUIR, A.M.I.E.E., *Vice-President, in the Chair).*

THE "FIXED STARS."

By Mr JOHN D. McDOUGALL.

CELESTIAL objects consist of the sun and moon, eight principal or major planets, about 700 minor planets, also comets and meteors. These all belong to what is called the Solar System. The remainder in astronomical terms are called the "fixed stars."

It is not intended to convey the idea that the "fixed stars" are not in motion, but this expression is used to distinguish between them and the planets. Planetary motion can be readily observed without optical aid, but stellar or star motion cannot be so observed. A great many of the stars are known to have proper motion, that is to say, the motion is not relative,but refers to the star itself; it is actually in motion. From the foregoing remarks it is to be noted the Solar System is not being dealt with in the limits of this paper; the system

of which our sun is the primary and to which the planets with their satellites belong. A great many of the names of the star groups have been handed down from the remotest antiquity, this being especially the case with those of the northern heavens. We speak of the "Constellations," which simply mean literally the star groups. If the same classification were adopted in relation to shires, towns, and villages, as are used in connection with the stars, then Glasgow would be "Alpha" Lanarkshire. "Alpha," because it is the city of most importance or the largest in this shire, and the appellation "Lanarkshire" because it falls into the list of places in this particular locality. The next important town would be called "Beta," then would follow the remainder according to their relative importance, with the letters of the Greek alphabet attached, gamma, delta, epsilon, zeta, eta, theta, and so on. When the whole of this alphabet has been exhausted numbers would be attached. This was first done by Flamsteed, and his numbers and name are still quoted when referring to stars. There are also catalogues of double stars, red stars, etc. Particular constellations are generally recognised by the contour or figure which is formed by their brightest stars, but it is very often, if not always, discovered, on referring to star maps, that this figure only forms a part of the group making generally the rough boundary. The first recorded classification of the stars was accomplished by Ptolemy in 150 A.D., who arranged the 1,022 stars observed by Hipparchus of Rhodes (called the father of astronomy) about one century before our era. Very few persons are acquainted with the star groups. Yet this knowledge, easily acquired, might well form part of the equipment of every educated person. There are interesting old legions and myths attached to these which are very suggestive and fanciful, and give one some insight into the productive imagination of our ancestors. A large amount of simple and healthy pleasure is lost to those who are content merely to stand and stare at the stars on a fine

frosty night without this knowledge. When the star groups are learned by name, and the chief stars therein are memorised, the sky becomes choke full of interest, and each successive annual return of some prominent and familiar group makes us feel as if we welcomed an old friend. Who has not felt thrilled when the winter nights are upon us and we hail again the noble form of "Orion"? Fig. 2.

Most books on astronomy, whether intended for student or amateur, give some method of learning the relative position of the different groups, generally starting with "ursa major" or the Plough, Fig. 1, and from thence drawing imaginary lines to the others. This is probably very good, but, in the opinion of the Author, it is better to learn to locate all the groups by their shape, or that of their brightest stars, and the relation of these groups to one another. By following this method memory work is reduced to a minimum, and this is something of an advantage to a beginner. The only constellation the Author knows from memory is Leo, Fig. 5, by drawing lines through Alpha and Beta. Ursae, Fig. 1, in the opposite direction to that of the Pole Star, the line will touch Leo. On cloudy nights when some stars are obscured and others visible of the same group, it is next to impossible to name these if the alignment method only is adopted, while there is a greater probability of doing so by the other method. Of course it must be admitted both systems are only a means to an end—the experienced observer discards both. The features of several of these groups are so striking that once they are carefully observed it is hardly possible for one to forget them. Say, for example, Cygnus—the Flying Swan—Fig. 7; Leo—the Crouching Lion—Fig. 5; Lyra—the Lyre—Fig. 10; Delphinus—the Dolphin—Fig. 13; Triangula—the northern Triangles—Fig. 11; Pegasus—the Winged Horse, making what is called the greater portion of the great square—Fig. 6; Corona Borealis—the Northern Crown—Fig. 12; Cassiopeia—the lady in the chair—Fig. 8. If one should think

of taking up the study seriously it is well to learn those first which lie in the Zodiac, or the Annual Path of the Sun, the zone in which the planets and moon move round the heavens. By such exercise he will more readily come to understand why the sun gets high up in Gemini—the twins—Fig. 4, and low down in Sagittarius—the archer—summer and winter respectively in the Northern hemisphere. No good or practical purpose would be served by enumerating all the constellations, but to give those an opportunity of being able to recognise some of the principle ones who may wish to interest themselves in this subject, a few are shown in the diagrams, Figs. 1 to 13. A number of celestial objects of particular interest alike to the professional astronomer and stargazer are to be found in these particular groups. To those who are without optical aid the brighter stars will appear to be of most importance, but this is oftener the exception than the rule with those who employ the telescope. Quite a large number of the interesting sights of the heavens are situated in relatively insignificant surroundings. For example, the Constellation of Cancer—the crab—lies between Gemini and Leo, Figs. 4 and 5 respectively. Its principal stars are only of the third magnitude and difficult to locate. In this constellation there is a cluster of small stars closely packed together at the centre and becoming scattered in proportion to their distance from it. It is called Præsape—the bees-hive, which it very closely resembles when seen with bees entering or leaving. It can be seen with a fairly good pair of binoculars. Sirius — the "dog star"—Fig. 9, might also be referred to as another example. It is the brightest star of the whole heavens, that is, it exceeds all other stars in apparent magnitude, yet it is the one solitary bright star in the constellation to which it belongs. The other members of this group are not easily distinguished, partly, it may be added, on account of their always being very close to our horizon, but also on account of the difference in magnitude between them and Sirius.

Generally speaking the brightest star in any constellation, whether of the first, second, or any other magnitude, is known by the Greek letter "Alpha"; the next brightest by "Beta"; the next by Gamma, and so on; the name of the constellation in which particular stars are located being affixed to their respective letter. In addition to this denomination quite a large number of the stars have a proper name. Alpha and Beta Geminorum are also called "Castor" and "Pollux"; Alpha and Beta Orionis "Betelgeuze" and "Rigel"; Alpha and Beta Cygni, "Denet" and "Albirio," and so on. It does not, however, follow that the respective letter attached to any star gives its true relative magnitude, as might be expected from these remarks. In some constellations Beta is relatively brighter than Alpha. Castor and Pollux may be cited as an illustration. The latter star, Pollux, is called Beta Geminorum, and is brighter than Castor or Alpha Geminorum. Rigel Beta Orionis is also brighter than Betelgeuze. The explanation of this anomaly lies in the fact that several stars have altered in magnitude since their allotted letter was attached to them—some having increased in luminosity and some the reverse. Stellar motions may be separated into two distinct divisions by their having distinct and different features—the one apparent, the other real motion. The apparent can be further sub-divided into diurnal, annual, and precessional. The first of these being the daily motion due to the revolution of the Earth on its axis. As the stars are practically fixed on the celestial sphere, and the Earth revolving from west to east, this revolution being accomplished with reference to the stars in 23 hours 56 minutes, it has the effect of apparently making the stars rise, to the observer, on some part of the Earth's eastern horizon between north and south, and also making them disappear, or set, from the observer's sight on the western horizon between north and south. The exact point of rising and setting being determined by what is called a star's declination, or its angular

distance from the Celestial Equator. The sun is spoken of as rising in the east and setting in the west, but this is only strictly correct on two occasions in a year, the 21st of March and 22nd September. On all other occasions it rises either north or south of east, and sets north on south of west. If one were to be placed in the centre of a room and turn himself round in the direction of his left hand or in the opposite direction to that in which the hands of a clock travel, all the objects on the walls would appear to him to turn round in the opposite direction, that is, from his left to his right hand, or in the same direction as the clock hands. Further, these objects would appear to move completely round in the same time in which he himself turned completely round. This represents the diurnal or daily motion of the stars. Fig. 15 illustrates this motion. The diagram shows the daily arcs of stars for the latitude of Glasgow. It will be noted that as the declination of stars increases the daily arc becomes greater, until some stars do not set, but continue to turn round the heavens both during the day and night. These are called "Circumpolar" Stars. The arc subtended between the Celestial Equator and the horizon at any locality is equal to the north Declination at which, or above which, stars do not set. See Fig. 17. Consequently, all those stars with North Declination greater than 34 degrees do not set at the latitude of Glasgow. Suppose one again were to be placed not at the centre of the room as before, but at a place midway between that and the walls, and in addition to turning himself round as before progresses in a circle in the same direction as his rotary motion, he will notice that at every complete revolution of his body it is not the same object which he will observe on the walls nearest to him as he saw at his former observation of the wall, but one further advanced. This would keep on being the case until he arrived at the position and place from which he started. This represents the annual apparent motion of the stars. See Fig. 16. The characters figured outside

of the Earth at the different positions in its orbit round the sun indicate what is called the sign for the Constellation. The particular sign marked adjacent to the Earth at any position shown is the sign of the Constellation diametrically opposite to that in which the sun is to be found in that month of the year. As twelve groups of stars are indicated by these signs, and called the "Zodiac," it can be seen from diagram No. 16 that at every revolution of the Earth the stars gradually change until the Earth coming to the position at which observation was first made the same stars are again seen. By careful observation, even without optical aid, it can easily be noticed that stars move towards the west, or clockwise, by the interval of four minutes of time daily when referred to any convenient fixed object, such as a gable end, a wall corner, or a flagpole. Suppose the Constellation of Orion, Fig. 2, be observed. It will be found due south or, astronomically expressed, on the "meridian," on the 22nd December at 12 o'clock midnight. On January 5th the following year (an interval of fourteen days) it will be found that it has moved to westward by 15 degrees, or one hour by the clock, at the same time as the observation was made, namely, 12 o'clock midnight, that is, it crossed the meridian at 11 o'clock. This progressive motion, as it might be called, is constantly going on. The stars of Orion cannot be seen by night in summer time on account of this, therefore, it is termed one of the winter constellations. If observation be made a year later it will be found that this same constellation will occupy practically the same position relative to the gable end, wall, or pole, on the same day of next year, namely, the 22nd December, at 12 p.m. When stars are actually on the meridian, which is a great circle of the Celestial sphere running due north and south through the observer's horizon and bisecting it, they are said to "culminate." After rising a star approaching it increases its apparent distance from the horizon, until it is actually on the meridian, when it then

begins to decrease in distance from the horizon until it disappears under it. The former apparent motion is called rising; the latter, setting! Circumpolar stars, or those stars which do not set at any particular latitude on account of their paths showing complete circles, at that latitude can be observed crossing this imaginary line both to north and south of the Celestial pole or axis of apparent rotation of tne heavens. These crossings are termed respectively their north and south culminations. The greatest altitude or distance from the horizon is reached when stars south. The interval of time between two culminations or the coincidences of a star with this line in reference to one rotation of the Earth is termed a Sidereal or Star Day, and, as previously remarked, is equal to 23 hours 56 minutes. It will thus be noted it is shorter than the Solar day, or that determined by the Sun's apparent motion, because the Sun in his apparent circuit of the heavens in an anti-clockwise direction has moved eastward, and the Earth has, consequently, to revolve through an additional interval in time to bring the Sun into the position which it occupied relatively at the previous observation. The annual interval, however, between the time a particular star coincided with the meridian to that in which it again did so, as was seen in the case of "Orion" already mentioned, is called a Sidereal or Star Year, and is practically of the same length as the Solar Year, the Sun being in practically the same place as a year previously in relation to a particular star. Theoretically all known stars lying closer to the North Pole of the Celestial Sphere than 34 degrees south of the Equator (Celestial) can be observed here, that is, in Glasgow, provided a convenient time be chosen, solely on account of this progressive motion. The whole Celestial Sphere down to 34 degrees south passes before us in one year like a huge panorama. Reference to Fig. 17 will demonstrate this. It will be noted that the word "practically" is used to qualify this statement referring to annual star motion, and this brings

us to the last of the subdivisions of apparent Stellar or Star motion, called "Precession." This phenomenon cannot be detected by ordinary observation except after long intervals of time. The most delicate and exact instruments used in astronomy are required to detect it in the course of a year. In this time it amounts to a quantity about equal to the diameter of a halfpenny removed from the observer to a distance of 300 yards. This progressive or forward motion of the stars, for this is the meaning of the word "Precession," is caused primarily by the inequality of the polar and equatorial diameters of the Earth. The polar is 27 miles shorter than the equatorial, or one part in 295 parts. If the Earth is assumed to be represented by a globe or ball having an equatorial diameter of 18 inches, then the length of the polar axis would be $17\frac{15}{16}$ inches. The equatorial being larger than the polar, the gravitational pull due to the Sun's mass is greater at the Equator than the Poles, and as the plane of the Earth's Equator does not coincide with the plane of its motion round the Sun, but is inclined to it at an angle of 23 degrees, $27\frac{1}{2}$ minutes (see Fig. 18), the consequence being the Sun's pull attempts to make the terrestrial equator settle down into the plane of the Ecliptic or the plane of the Earth's annual path round the Sun. This disturbs the rotational equilibrium of the Earth and makes it as it were wobble, describing with its polar extremities a circle round the pole of the Ecliptic or the pole of its Annual path. (See Fig. 19.) During the period between 21st March, when the Sun is on the Equator on his northward journey, until he reached the tropic of Cancer on June 22nd, the Summer Solstice, and then descends again to the Equator, which he reaches on September 21st, the Autumnal Equinox, the effect of his gravitational pull is to lift the Equator of the Earth upwards or northwards, while from September 22nd, the Equinox, through the time when he is on the tropic of Capricornus to the Vernal Equinox, March 21st, this pull tends to depress

the terrestrial Equator. At both of the Equinoxes when the Sun is over the Equator and a point on the Equator faces or is in line with the Solar Centre, there is no action of this nature. The Earth behaves exactly as a gyroscope in motion, any force applied to it so as to change the direction in which the axis points only compels it to describe a circle around the original position. The time required for a particular star to make a complete revolution of the heavens from this cause occupies about 25,800 years, the annual amount being 50·2 seconds of arc. Accuracy in determining the annual value of this apparent motion is much simplified if the co-ordinates of stars given in star maps and catalogues of the past are compared with their present positions in respect to the Sun's place. About 2000 years ago the Vernal Equinox (one of the points of intersection of the plane of the Earth's Equator and the plane of the Earth's path round the Sun, or the place occupied by the Sun on March 21st, 12 hours 3 minutes in 1910) was situated in the Constellation of Aries (the Ram) whereas at the present time it is in that of Pisces (the Fishes). This point is always termed the first point of Aries, irrespective of the particular constellation in whch it may be situated. It, therefore, follows that what is called the sign for a particular constellation of the Zodiac has moved by this cause (precession) into the constellation immediately in front of it, a retrograde direction or clockwise. In using the signs it is supposed no change has occurred, but assuming the Sun's position to be what it was 2000 years ago another motion possibly might be added to those already spoken of, called "Annual Parallax." If the Solar System were travelling collectively through space it would be expected that the apparent motions of the stars due to the former motion would all diverge from a certain point, if the directions they pursued were projected backwards in straight lines, the point of intersection of all the lines would represent the place in the Celestial sphere to which our Sun, the Earth, and all the

members of our system were hastening. It is also obvious that the diametrically opposite point in the heavens called the anti-apex of the Sun's way, would have all the paths of stars converging upon it, if they were extended backwards in straight lines. This is precisely what happens when we travel in a tramway car along the rails. If we see far enough ahead, those rails in front of us appear to diverge as we move forward, while if we look behind the moving car the rails appear to be closing together. To find the apex of the Sun's way in space appears a simple problem, but it is far from being such. The proper or individual motion of a large number of stars must first be known, and the observed change of position due to this proper motion deducted from the observed total before the position of the apex can be determined, and this has proved to be in practice a difficult problem. The majority of those competent to express an opinion on this matter say the Earth is travelling towards a point in the Celestial sphere not far from Vega, or Alpha Lyra, see Fig. 10, at the velocity of 150 million miles per annum, or about 4 miles per second. There are two stellar motions, which are real, termed "Orbital" and "Proper Motion." It is quite possible both may be the same in principle, although they aparently differ. Stars move round their common centre of gravity much the same as in the case of the Earth and Moon. More attention will be devoted to this when dealing with multiple stars. This is called "Orbital" motion, as they describe closed geometrical curves round the common centre of gravity. In proper motion a star has a motion of its own through space from us, to us, across our line of sight, or in any intermediate direction, sometimes partaking in movement common to a family of suns, closely associated or obscurely connected to some widely removed star or stars. It is quite possible all Celestial motions are approximately circular, or conform to geometrical curves, although they appear to be rectilineal or in straight lines. The paths may be of such

large radius that to us they appear straight owing to the smallness of the part we are able to observe.

There is a star of $8\frac{1}{2}$ magnitude which moves across our line of sight at the velocity of 80 miles per second. Arcturus (a Bootis) is moving at the velocity of 200 miles per second at the least, according to Newcombe, 54 miles according to Sir David Gill, 55 according to Heath, which is three times faster than the Earth travels round the Sun, and the speed at which the Earth accomplishes her journey is 1,000 times faster than an ordinary railway train. The actual distances of the stars are so enormous that employing our ordinary standards we entirely fail to comprehend them. There are two forms of unit used in expressing their distances, one of these being multiples of the Sun's mean distance from the Earth, it being taken as the unit. The other termed light years, or the distance is expressed by the number of years which light requires to cross from a particular star to us, the unit in this case being the distance which light travels in a year, or 63,368 times the distance from the Earth to the Sun, $63,368 \times 92$ millions.

	STAR				
1.	A. Centauri, -	224,000	times	the Sun's	distance.
2.	61 Cygni - -	366,000	,,	,,	,,
3.	1830 Groombridge,	912,000	,,	,,	,,
4.	70 Ophinchi, -	1,286,000	,,	,,	,,
5.	A. Lyrae, - -	1,337,000	,,	,,	,,
6.	Sirius, - -	1,375,000	,,	,,	,,
7.	Arcturus, - -	1,624,000	,,	,,	,,
8.	Polaris, - -	3,078,000	,,	,,	,,
9.	Capella, - -	4,484,000	,,	,,	,,

1.	A. Centauri, - -	4·4	light years	distant	from us.
2.	61 Cygni, - - -	8·8	,,	,,	,,
3.					
4.					

5.	A. Lyrae, - -	27·2	light years distant from us.		
6.	Sirius, - - -	8·8	,,	,,	,,
7.					
8.	Polaris, - - -	46·5	,,	,,	,,
9.	Capella, - - -	27·2	,,	,,	,,
	Procyon, - - -	10·9	,,	,,	,,
	Altair, - - -	14·2	,,	,,	,,
	Eta Cassiopeia, - -	15·5	,,	,,	,,
	Aldebaran, - -	21·7	,,	,,	,,

It has been found by experiment and verified practically by the satellites of Jupiter that light travels seven times round the Earth's equator in one second of time, or at a velocity closely approaching 186,330 miles per second. From our Sun light requires 8 minutes 18 seconds to arrive at the Earth. From the nearest fixed star it requires the interval of four years 4 months 23 days. The star is Alpha Centauri; it cannot be seen here. The nearest star to the Earth visible in Glasgow is "Sirius," called the Dog Star, seen in our winter months under the Constellation of Orion, Fig. 2, and a little to the left hand when the observer is facing south. Light emanating from it requires 8 years and 9 months to arrive at our eyes. In the case of Capella (A. Aurigæ), or the Goat, it requires 27 years 2 months and twelve days, and in that of Polaris, the Pole Star, it requires 46 years and 6 months. From measurements it has been estimated that light requires on the average 15½ years to come to us from stars of the first magnitude, that is, the brightest stars; 28 years for the second; 43 years for the third; and so on, until for those of the twelfth magnitude it requires 3,500 years. The nearest star to us, according to Sir Norman Lockyer, is at a distance of 19,000,000,000,000 miles from us, while the more distant ones are so far off that light, though travelling at this prodigious speed, 186,330 miles per second, requires an interval of 50,000 years to dart from them to our eyes. No star with

a known parallax exceeds 1 second angular, the equivalent of even this quantity is equal to the angle subtended at the observer's eye by a penny piece seen from 4 miles off. Granting a star has a parallax of one second of arc (for simplicity) it really means it is removed from us to 206·265 times the Sun's mean distance from us, or 206,265 times 92 millions. So far as the Author can discover the parallax of 51 stars has been determined, and selecting the first and last of this list as given, Alpha Centauri has a parallax of ·75, being equivalent to a distance of 224,000 times that of the Sun, while Capella and Polaris are removed 3,078,000 and 4,484,000 times this distance from us. To enable us to form some tangible idea of the immensity of interstellar space let us imagine our Sun to be a ball or globe 2 feet in diameter, or two-thirds of a yard across; the Earth an ordinary green pea, distant from the imaginary Sun by 71⅔ yards; then on the same scale our nearest stellar neighbour, represented by a ball about the same diameter as the imaginary sun, namely, 2 feet, would require to be placed at a distance of 9,000 miles. When stating star distances quite a large amount of scepticism is displayed by intelligent people, and very often they are supposed by them to be mere assumption; but this is not so. No doubt there are errors, but they are approximately accurate.

To give some idea of the method employed to determine those distances let us begin by supposing we are dealing with our Moon and endeavouring to find her distance from us. The exact distance between two stations on the Earth's surface, say, for example, two observatories, is carefully measured, the method employed being chain measurement and triangulation, the observatories being, as far as circumstances permit, on the same circle of longitude, or, to be more commonplace, having the same time by the sun or clock. The observatories in actual practice were Greenwich and the Cape of Good Hope, see Fig. 21. From both of these places simultaneously the angular distance between the centre

of the Moon's disc and a particluar star or stars in close proximity is measured by means of movable spider wires in the field of the telescope, each of two wires being made to coincide with the Moon's centre and the star, at the same time noting the revolutions and parts of revolutions through which the screw carrying the wires is moved. When the measurements from the two stations are compared subsequently, the difference between the two supplies the necessary data to calculate her distance from the Earth. Referring to the diagram, Fig. 21, it will be noted that as all lines from the Earth to a star are sensibly parallel, the observer furthest north on the Earth sees the Moon depressed below the star "X," while an observer at the southern station sees the Moon to north of the same star. The arrangements for observations of this nature are made beforehand, and at the exact moment of observation an electric signal passes between the observers. By this means the mean horizontal parallax of the Moon has been found to be 57 minutes 2·707 seconds, or equivalent to a mean distance from the Earth of $60\frac{1}{4}$ times the equatorial radius of the Earth. To simplify this method of obtaining distances, let us imagine we are looking along a street at night time having the usual lamps on the pavement edge. Again, suppose, Fig. 20, a red lamp "E" to be in the middle of the street, usually seen on barricades surrounding street repairs. Now, suppose we stand on one pavement at "C" and bring the red lamp "E" into line with a further distant white light lamp, which we will call "A." Crossing directly over the street we notice the red lamp moves away from "A" in the opposite direction to that in which we are moving until we stop at the point "D," when it falls in line with another white light lamp, "B." Standing at "D" and measuring the angular distance between our first position "C" and "E," and again repeating this measurement from the position "C" and the angle "DE," then by measuring the length of the base line we can state the

distance from the centre of the base, or the vertical distance from the base line to the red lamp "E." This apparent change of position of the red lamp due to our observing it from two different positions is exactly what is meant by the term parallax. The same principle is employed to find the distances of the stars, although they are so far removed from us no base line upon the Earth is capable of showing any parallax at all. Indeed, the Sun's parallax is only of the angular value of 8·80 seconds. Putting this in another form, an observer on the Sun, measuring the diameter of the Earth, would find it to be about 17½ inches angular, that is, 7,400 earths would be required to surround the Celestial Sphere in the plane of the Sun's equator. We are, therefore, compelled to search for a new base line, and that the largest possible. Roughly speaking, we are carried through space between the months of December and June in a straight line equal to 182,860,000 miles. If we select two or more stars, one of them being the star of which the parallax is required. This star is generally brighter than the others, as we presume it is closer to us by this inference. We observe the angular distances between the bright star and its comparison stars very accurately with the assistance of the telescope and moveable spider or other extremely fine wires in the field, say, in the month of December. We then, after an interval of six months, go through the same operation. If, on referring to our angular distances noted previously and those we have obtained in the month of June, there is any difference, then we have reason to suppose the star is at a measurable distance from us. The unit employed is the mean distance of the Earth from the Sun. The working out is as follows—If a star has been found to apparently change its position, due to the motion of the Earth in its orbit by 1 second angular, it follows, then, an observer on that star (if by any possibility there was one) would also observe the Earth moving through 1 second angular during a six months' interval. Now, there

are 360 degrees multiplied by 60 minutes multiplied by 60 seconds, amounting to 1,296,000 seconds in the circumference of any circle, and dividing this by the radius 6·28318 we get 206,265 seconds in a radius. Now, one second has been assumed to be equal to the Sun's mean distance from the Earth, at the star in question, or 91,430,000 miles; therefore, the distance of that star from us is 206,265 times 91,430,000 miles. It seems likely that about 50 stars only are within seven times the distance of Alpha Centauri, the nearest star to the Earth. If the bright stars are so on account of their relative proximity to us (although there is some reason to doubt this), then those whose images are seen on the plates of large photographic telescopes only must be more than a thousand times this distance. We are not aware of any parallax having been found for Alpha Argus or Canopus, consequently we do not know its distance from us, yet it is the second brightest star of the heavens. From recent calculations based on totally different principles five stars of Ursa Major, Fig. 1, Beta to Zeta, have been found to be distant from us 180 light years, or twelve million times the Sun's distance from the Earth, while light takes 60 years to cross from the first to the fifth of these stars. It has been estimated that about 6,000 stars can be seen with the naked eye, and as only half of the Celestial Sphere can be seen at any one time it follows that only about 3,000 ought to be seen, but the number is further reduced owing to low lying dense vapours and smoke usually present in all cities. In powerful telescopes twenty millions are visible, and it is probable that by employing giant instruments the number is raised to one hundred millions. As an example, let us refer to the Pleiades, Fig. 14, the Seven Sisters of Atlas, a familiar group. Six, seven, or even eleven of this cluster may be detected by the naked eye. A small telescope, say a 2-inch refractor with an eyepiece magnifying 19 times, will enable us to detect over 50 stars. The Author has with this power

counted 52. On the photographic plates of a modern astrographic refractor (an instrument specially designed for photographic work on the heavens) of 13-inch aperture, the number revealed to us is 2,326 in this group. Parts of the heavens which to the eye alone apparently contain one star, can be seen to contain a thousand with the assistance of a moderate telescope, while 10,000 can be seen with a large instrument. The double cluster, as it is called, in the Constellation of Perseus is to the eye a patch of faint nebulosity; a 2-inch telescope reveals a dense mass of glittering stellar points; while using a 6½-inch telescope it is almost impossible to estimate the number. In a large telescope the "milky way" is seen to consist of myriads of stars which can only be estimated in number, yet to the naked eye on a fine night it only appears as a faint nebulous streak or a faint cloud of steam. The star cluster in Hercules cannot be seen with the unaided eye, and yet Herschel estimated the number of stars which it contains to be 14,000. A moderate telescope, say of 6½-inch aperture, cannot resolve these individual stars in it; they only appear as a nebula. This cluster was discovered by Halley of Comet fame in 1714. The spiral nebula in Canes Venatici, and also in Andromeda, are apparently dense clusters of stars from the evidence of their spectrum, yet no telescope up to the present can separate the individual stars composing them. The stars shine with variously coloured light. There are scarlet stars, red stars, blue, green, and yellow stars. They are so diverse in colour that observers try in vain to define them, so completely do they shade into one another. Under *red stars* there is Aldebaran, Fig. 3, Betelgeuze, Fig. 2, and Antares in the Scorpion. *Blue stars*, Rigel and Bellatrix, Fig. 2, and Spica in the Virgin. *Green stars*, Sirius, Fig. 9, Vega, Fig. 10, Altair in the Eagle, and Deneb, Fig. 7. *Yellow stars*, Arcturus, a Boötis, and Capella in the Waggoner. *White stars*, Regulus, Fig. 5, Denebola, Fig. 5, Fomalhaut in the Southern Fishes, and Polaris, the

Pole Star. The most striking examples of coloured stars are to be found in the components of double systems. In Gamma Andromedæ the largest star is yellow, while the smaller companion is blue green. In Eta Cassiopeiæ the larger star is white, while the companion is rich ruddy purple. Some stars appear of a deep red, almost as deep as that of blood. Sir John Herschel, in commenting upon a group in the southern heavens, said it resembled "a superb piece of fancy jewellery" Of 100 stars, which this group contains, seven of this number alone exceed the 10th magnitude, the remainder being fainter; two are red, two green, three pale green, and one greenish blue. Stars of a reddish colour are not uncommon, say, from orange yellow to deep orange. Several of the first magnitude belong to this class. It is, however, to the smaller stars attention must be given to see the real blues and greens, this being especially so in the smaller components of double systems. The smaller star of Beta Cygni, Albireo, Fig. 7, is blue, while the larger star is yellow. The smaller star of Gamma Leonis, Fig. 5, called Algieba, is greenish yellow, while the large star is yellow. The colours of these stars can easily be distinguished in a small telescope. It is to be noted that, referring to former records of star colours, several appear to have changed. Sirius in ancient records was said to be red, as was also Capella. Observers do not always agree as to the colour of particular stars, but this will not surprise anyone who has tried the experiment of detecting their colours. The lucid stars, those visible to the naked eye, are better for experimental work when using the eye alone. Select, for example, Vega, Alpha Lyræ, and Alpha Boötis, they can both be seen in the sky at the same time. Looking carefully at one of these stars, and then suddenly turning round, it will at once become evident that Vega is of a blueish tinge while Arcturus is of a reddish hue. It is much easier to determine the colour of small stars with the assistance of the telescope than that of the brighter ones, as the intensity of

the illumination in the latter seems to affect the sensitiveness of the eye to appreciate colours, and very often atmospheric boiling makes it impossible to single out from several any predominating colour. An indication of the physical constitution of stars and the stage at which they have arrived in the evolutionay process is indicated generally by their particular colour. This will be referred to later.

Employing the telescope, the apparent size of all stars is seen merely as a point of light. They are so infinitely removed from us in the depth of space that the most powerful telescope cannot increase their apparent size; indeed, the larger the telescope employed the smaller does the image become. When the magnification in any telescope is increased up to and beyond a certain point, determined by the quality of its object glass, little round discs or moons appear in place of the stellar points, with a number of what are called in optics "diffraction rings" surrounding these discs and concentric with them. (See Fig. 26, centre of bottom row.) These, however, are not the actual apparent sizes of stars. They are termed "spurious discs" and are caused by optical phenomena, or may be in addition to this, caused by the imperfection of the telescope object glass. It may then be asked, why increase the size and power of telescopes? The reason for this will be seen later when dealing with multiple star systems, and as far as the limits of this paper will permit. A large window in a room allows more light to pass into a room than a smaller window, the amount passing through being proportional to the area and the quality of the glass. So is it with telescopes. What is required and demanded at homes is also what is required and demanded in telescopes —"more light." A small perfect telescope is as capable of dealing with the sizes of stars as large ones. The smallest object is the mathematical point, the image of a star seen in a telescope without magnitude; yet the largest object in the universe, so far as the Author is aware, at present is the

star "Canopus," Alpha Argus, said to be one million times the mass of our Sun. Sir David Gill gives as its luminosity an equivalent to 20,320 times that of our Sun. Notwithstanding this it appears in the telescope nearly as a point without dimension. The remarkable star in the Constellation of Perseus, called Beta Persei, or "Algol," the "demon star," on account of its "slowly winking eye," has attracted the attention of observers for several centuries. It is termed a spectroscopic binary, as it can only be detected as a binary, having two components with the assistance of the spectroscope and cannot be seen with the most powerful of our telescopes. The two stellar components are respectively one million miles in diameter and 800,000 miles in diameter, the latter, the smaller, being just about as large as our Sun. Their combined mass, however, is only two-thirds of the Sun's, each being two-ninths and four-ninths respectively. The combined mass of the components of the binary Beta Aurigæ are equal to six times that of the Sun. Sirius or Alpha Canis Major, Fig. 9, is thirty times brighter than the Sun. The Sun himself, equal to one million three hundred thousand globes the size of the Earth, and measuring 866,500 miles in diameter, is by no means a large star, and it is well for us that this is so. If the Earth were removed into such close proximity to Canopus as it is to the Sun, the heat would prove rather uncomfortable, at anyrate, for the few seconds during which it would exist. When individual stars are carefully examined in the telescope it becomes evident that several of those which appear to the eye alone as single are really not so. Several are thus seen to have two or more components closely associated. This may be due to one being in line with, and nearly in front of, the other, but we know there are many in which the components revolve around their common centre of gravity. Newton's enunciation of the law of gravity states that every particle in the universe attracts every other particle with a force proportional to the quantities

of matter in each, and inversely proportional to the square of the distance between them. While it is generally recognised that the Sun attracts the Earth, it is not generally known, although quite correct, that the Earth attracts the Sun, the preponderance of mass in the Sun's favour, however, making the latter attraction in its effect negligible. The common centre of gravity of Sun and Earth being located at a point within the body of the Sun, 278 miles from his centre, or 432,922 miles from the surface. The centre of gravity of the planet Jupiter, however, is located entirely outside of the Sun, in space, at a point 455,000 miles from the Sun's centre, or 21,800 miles from the Solar Surface. The components of star systems also obey this same law, revolving round one another, or, rather, round their common centre of gravity. In the year 1665 the star Gamma Arietis was seen double by Hooke, the first of our countrymen to do so in the case of any double star. The duplicity, however, of Mizar (see Fig. 1) was detected in 1650, the "comes" or companion to the principal star of this double being pale green and of 4·2 magnitude. The multiple star, Theta Orionis (see Figs. 2 and 26), which is located in the nebula, was discovered to be such in 1656. No double or multiple stars properly so-called can be seen as such with the eye unassisted by optical instruments. The double star Mizar, already referred to, Fig. 1, is wrongly spoken of as a naked eye double. The small star seen with the eye alone close to Mizar is not one of the double components, but a small star called "Alcor," or the test star. Employing even a small telescope, Alcor is widely separated from both components of Mizar. Another star, in fact, not detected by the eye, appears between Alcor and Mizar. Polaris, the present Pole Star, which is located on hour xii. on Fig. 1 at the point outside the margin where the converging lines meet, and nearly in line with the stars Alpha and Beta, Merak and Dubhe (called the pointers) has a small comes lying very close to it. It is not easily seen,

although the contrary is often affirmed. The Author is unable to say definitely he has seen it with any magnification from 16 up to 127 on a 2-inch refractor, but can detect it with a magnification of 60 on a 6½-inch reflecting telescope.

Six thousand double stars have been catalogued up to the present, and the periods of revolution of several have been deduced from observation. Of this number 700 are binaries, or suspected of being so, their components being in motion, the period ranging from 36 years in the case of Zeta Hercules, Fig. 26, 170 years in that of Gamma Virginis, Fig. 26, to 1,200 years in that of Gamma Leonis, Fig. 5, star Algieba. Epsilon Lyræ is composed of four stars, Fig. 10, and is called the "double double." An opera glass will show two stars, while a moderate telescope with magnification 100 will show the two doubles. Each pair of stars revolve round their common centre of gravity, while both pairs also revolve around the common centre of gravity of the pairs. The period of revolution of one pair being 1,000 years, that of the other 2,000 years, while the complete period of the multiple is one million years. The Star Castor Alpha Geminorum, Fig. 4 and Fig. 26, is a well-known double. It can be so seen with a magnification of 16 times on a small telescope. The observations made by Herschel on this star enabled him to detect its duplicity. Theta Orionis, Fig. 2 and Fig. 26 in the Nebula, consists of six stars, four of which can be seen in a 2-inch telescope. Sigma of the same constellation contains six which can all be seen in a 3-inch telescope. Several stars are known to be double although one of two components has never been seen. Algol has already been referred to as an example. Beta Aurigæ is another, and the diameter of telescope required to show it as such has been estimated as 80 feet. Beta Lyræ, Fig. 10, has two satellites revolving round it, as shall appear later on, and are comparatively dark bodies which cannot be seen. If observations of the same stars are made at intervals it will be noticed that some of them vary in luminosity. Some

cannot be seen without a telescope at minimum, while they can easily be seen at maximum luminosity with the naked eye. Some authorities consider temporary or new stars to belong to this class. Algol, which can be seen at all seasons of the year in Glasgow when the nights are favourable, shines as a star of the second magnitude for about 59 hours, then it suddenly begins to fade, until it drops to magnitude $3\frac{1}{2}$ in the period of $4\frac{1}{2}$ hours, losing two-thirds of normal brilliancy in so short a period. It remains thus for 15 minutes, and in 5 hours more recovers its normal brilliancy. See Fig. 22. The explanation of this change of lustre will be discovered by referring to Fig. 23. The brighter star seen by us is partially eclipsed by its darker companion once during every revolution. Beta Lyræ, Figs. 10 and 24, is also a variable star. Without going into detail it may be remarked that it can easily be observed to change in brilliancy owing to the close proximity of Gamma Lyræ, a comparison star which is not subject to fluctuations of luminosity. This star, Beta Lyræ or System of Stars, has two periods of fluctuations, shown by the curve on Fig. 24, differing from one another. The fluctuations are apparently caused by two satellites consecutively eclipsing the bright component. These are all termed "regular" variables, as their luminous condition for any definite time may be predicted, but in Omicron Ceti, called "Mira," the "wonder star," it has been found impossible to do so, therefore it is termed an "irregular" variable. Fig. 25. Its period of fluctuation cannot be determined accurately, although it closely approaches 301 days. The minimum also is uncertain, Heath giving it as the ninth magnitude. Its luminosity at maximum is at least 200 times greater than when at minimum. Several features which belong to it are at present a mystery. The lines in its spectrum change from dark at minimum to bright at maximum, indicating stupendous alterations in its physical constitution. Possibly at minimum it resembles our Sun, a comparatively

dense metallic neucleus surrounded by glowing vapours, giving off by the process of ebullition, while at maximum it apparently consists entirely of incandescent metallic and non-metallic vapours. The number of variables in northern skies is 120, while those suspected of being so number 400. The beginner with even the humble opera glass has thus a favourable opportunity for doing some original work. The most modern instrumental equipment of the observatory is the spectroscope. Essentially it consists of a piece of carefully worked and polished glass, called a prism. When it is placed in such a position that it intercepts a beam or pencil of light it has the property of changing its direction and also of decomposing the beam or pencil by splitting the light up into its different component colours. The colour band terminated at one extremity by red and at the other by violet is called a "continuous spectrum," as it runs without any interruption through red, orange, yellow, green, blue, and violet, the one colour shading into the other without apparent break in the continuity. With an ordinary single prism of glass the length of the band from red to violet is comparatively narrow, but with prisms of a particular quality and shape, or several associated in a train, the length of this band can be considerably increased. This is termed increasing the "dispersion," or scattering the colours more. It is found when this is done that in addition to the continuous spectrum the coloured band is crossed at right angles to its length by a considerable number of lines at all parts of its length. Some have probably noticed the same effect, that is, the coloured band, caused by the sunlight or gaslight being decomposed on the bevelled edge of a bedroom wardrobe, or on the triangular hanging ornaments of the now old-fashioned gasalier. In some cases these lines in the spectrum are bright, in others, dark. The former are called "radiation" lines, and the latter "absorption" lines. These lines have been found to indicate the character of the illuminating object. The bright lines are caused by incandes-

cent gas alone, either at a high or low temperature, while the dark lines are caused by the absorption of light taking place in gas or vapour as it passes from an incandescent liquid or solid source through this vapour to our eyes or to the spectroscope. The spectrum of the Sun consists principally of dark lines. Light emanating from the photosphere, or source of the solar light, being absorbed in the chromosphere, or gaseous envelope surrounding the photosphere. On this account it is sometimes spoken of as the "reversing layer." Employing a powerful spectroscope, or one of great dispersion, and measuring the exact position of these lines by means of some micrometer attachment to the eyepiece, such, for instance, as movable spider wires, in the field; then using this same spectroscope in the laboratory to analyse the light produced by known elements, it has been found possible by the coincidence of these lines to infer what constituted the source of light in the Sun and stars. Several lines belong exclusively to certain elements, are prominent and well known. See Fig. 27. Glowing hydrogen produces the C.F. and H. lines in the red, blue, and violet—Oxygen, 2 in the red called the A and B lines; Sodium, 2 well-known lines in the yellow called the D^1 and D^2 lines; Iron and calcium, 2 in the blue, 3 in the green called the "G and E" lines; Magnesium, 1 in the green called the "b" line; Calcium, 2 in the violet called the "H and K" lines. The true nebulæ give bright lines, such as that in Orion, Fig. 2, consequently it is inferred it is a large mass of incandescent gas. Stars are found to give both dark and bright lines, such as Mira, the "wonder star," already referred to, and some others. Stars have been classified according to the nature of their spectra. Those partly nebular fall into the first group; those consisting of glowing metals surrounded by gases burning at a high temperature into the second; those whose light has partially left them, owing to their decrease in temperatures, into the third group; those partially condensed or burnt out into the fourth group, similar

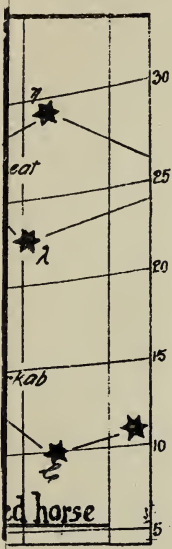
to the "Comes" to Algol; and those represented by bodies such as the Earth, into the fifth group. In Pi Cygni, which gives a radiation or bright line spectrum, we are possibly dealing with a nebula. The spectra of this class show a remarkable similarity to that of the nebulæ, and, therefore, it is probable this is the first stage in the life history of stars. The next stage of development is probably arrived at in stars of mixed spectra having both dark and bright lines in their spectra, while those giving dark lines only are in the later stages of development. Red stars generally give lines at the red end of the spectrum, such, for example, as Aldebaran, Fig. 3; Arcturus (A Boötis), and Antares (A Scorpii). The intermediate temperatures are represented by Vega, Fig. 10, Sirius, Fig. 9, and Altair (A Aquilæ); while in such stars as Rigel, Fig. 2, the highest temperatures are found. It is suggestive and worthy of attention that the elements most widely diffused among the stars, including hydrogen sodium, magnesium and iron, are closely connected with the living organisms of our own globe. The temperature existing within the glowing nucleus of any of these stars is unknown, as it must transcend any human conception. The temperature required to raise steam from water we know, but that required to raise vapour from iron we have no conception of. The electric furnace produces the most intense heat known or possible to us at present, but it falls very far short of that even obtaining in our Sun. The most intense illuminant known to us is the oxyhydrogen lime-light, yet if we examine the incandescent lime cylinder through the same piece of neutral or smoked glass as the Sun, the former appears black compared to the Solar light. Our Sun is by no means one of the hottest or largest stars. If it were removed from its present position to the average distance of a star of unit or 1st magnitude, it would appear to us as being of the 5th magnitude, and would be just at about the limit of visibility to us. Indeed, to the inhabitants of a city such as Glasgow we would not

have the privilege of seeing it very often, except with the assistance of a telescope.

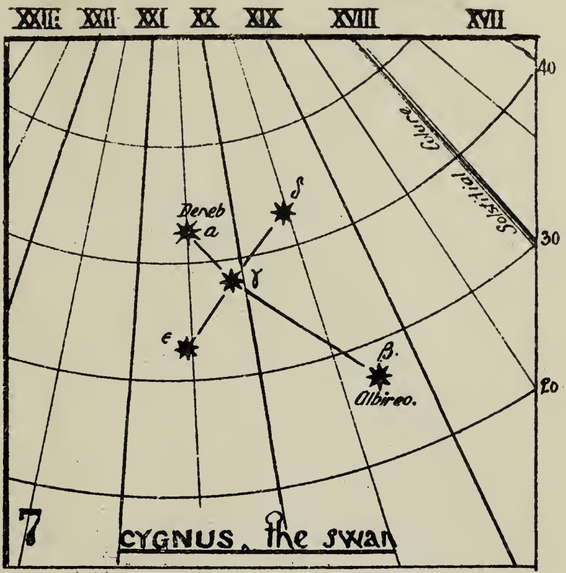
Discussion followed in which several gentlemen took part.

Mr R. M. Laurence (Student Member) requested Mr McDougall to explain the terms "Right Ascension," "First point of Aries," also, which star was of unit magnitude—he had been under the impression that Alpha Centauri was that star.

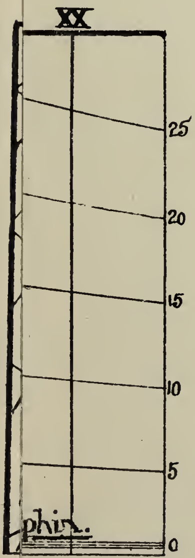
In reply to Mr Laurence, Mr McDougall said—The term "Right Ascension" is applied to one of the co-ordinates for finding the position of stars. It is measured from the "first point of Aries" round the heavens anti-clockwise. The Celestial Sphere is divided into 24 hours, called hours of "Right Ascension," written R.A. The angular distance of a star horizontally from this point is expressed in hours, minutes and seconds of R. A. It corresponds to longitude on the terrestrial globe, but must not be confused with Celestial longitude, another co-ordinate of the Celestial Sphere. All the circles of R. A. pass through the poles, bisect the equator, and are at right angles to it. The "first point of Aries" is a point on the Celestial equator where the Sun was situated on the 21st day of March, 1910, 3 minutes past noon, as will be noticed on referring to the paper. This point always is on the meridian when a Sidereal or Star Clock indicates Oh., Om., O seconds. The star taken as unit magnitude is Aldebaran Alpha Tauri, and will be seen on Fig. 3. Those stars which are brighter are denoted by minus units, as, for example, Canopus A. Argus – 1·0. Sirius A. Canis Majoris, Fig. 9, the brightest of all the stars, – 1·4 magnitude. Those less than unit magnitude are denoted by full numbers, and fractions to tenths, for example, Regulus, Fig. 5, 1·3 magnitude; Dubhe, Fig. 1, 2·0 magnitude;



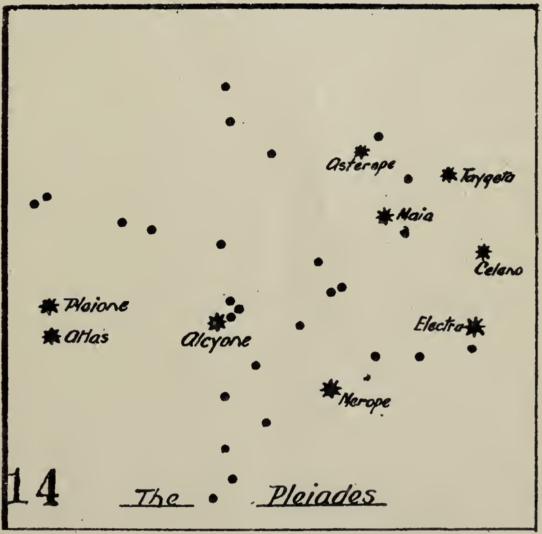
ed horse



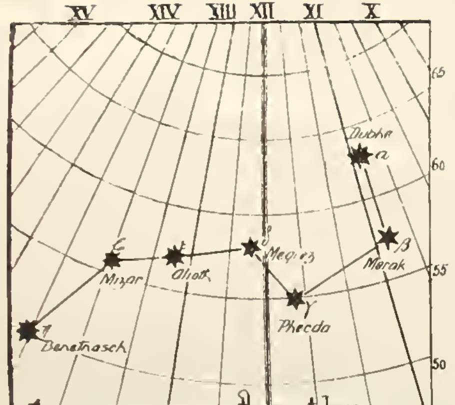
7 CYGNUS, the swan



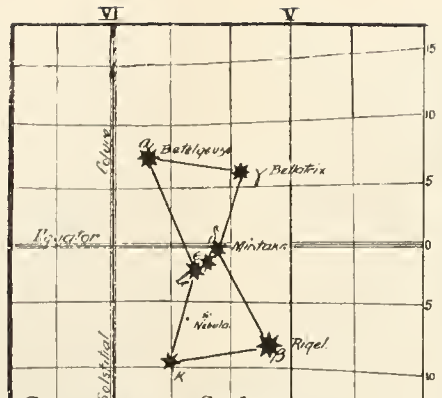
phin.



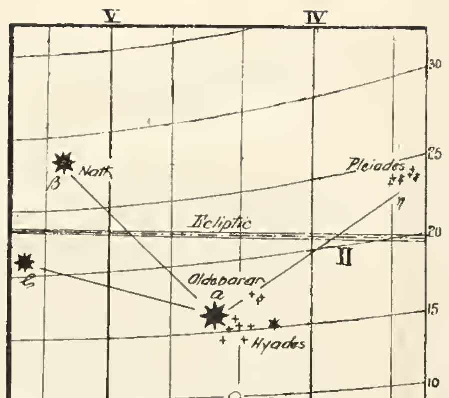
14 The Pleiades



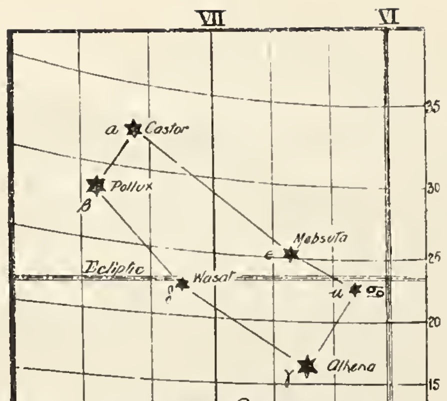
1 URSA MAJOR, the great bear.



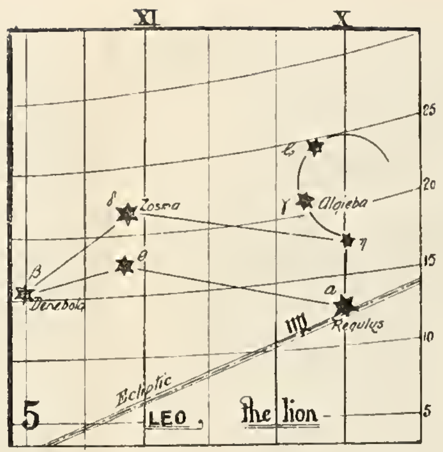
2 ORION, the hunter



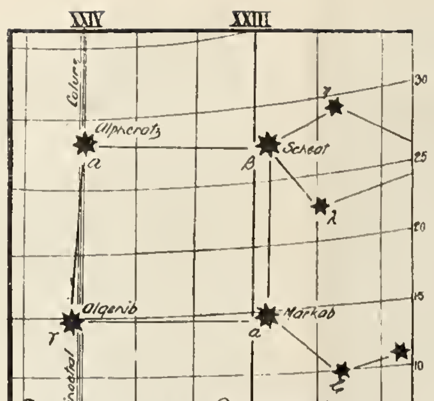
3 TAURUS, the bull.



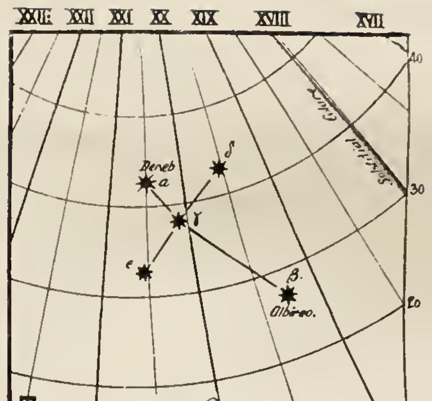
4 GEMINI, the twins.



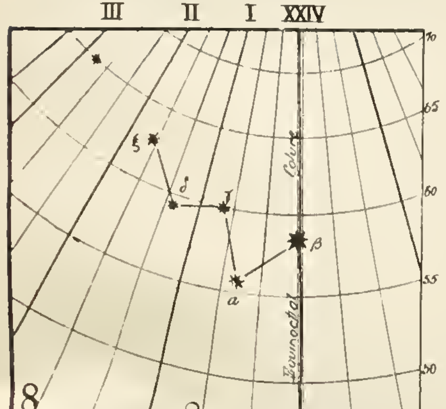
5 LEO, the lion



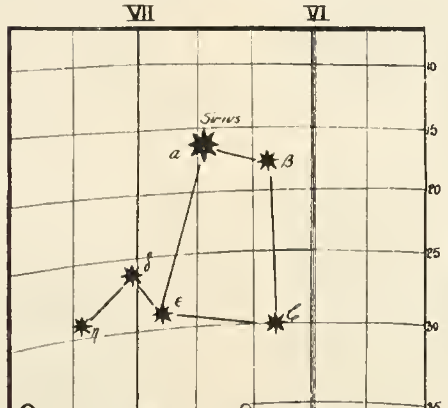
6 PEGASUS, the winged horse



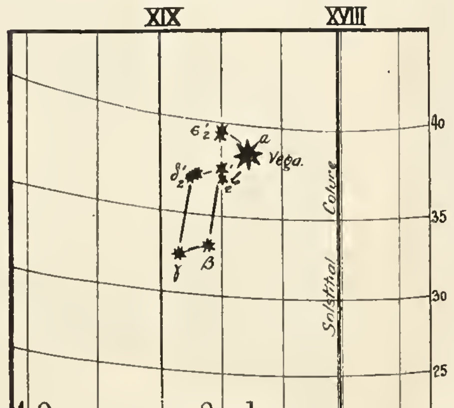
7 CYGNUS, the swan



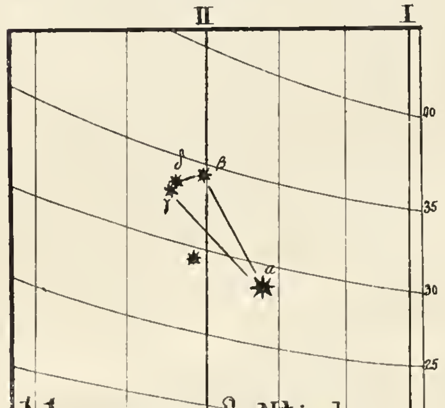
8 CASSIOPEIA, the lady in the chair

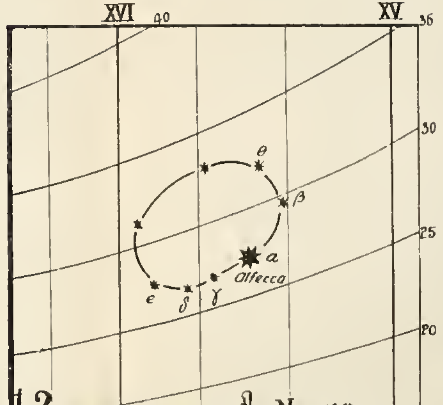


9 CANIS MAJ, the great dog

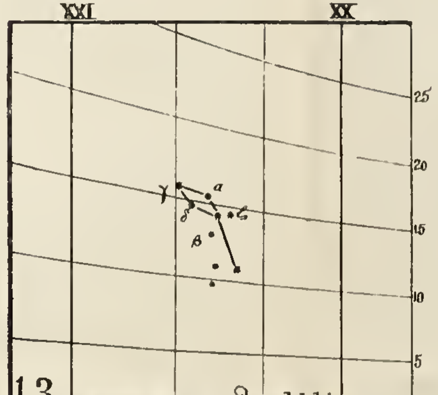


10 LYRA, the lyre.

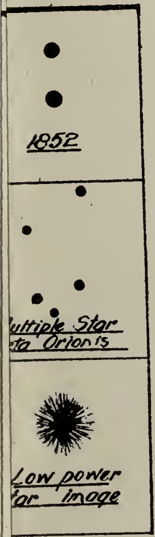

11 TRIANGULA, the N. triangles

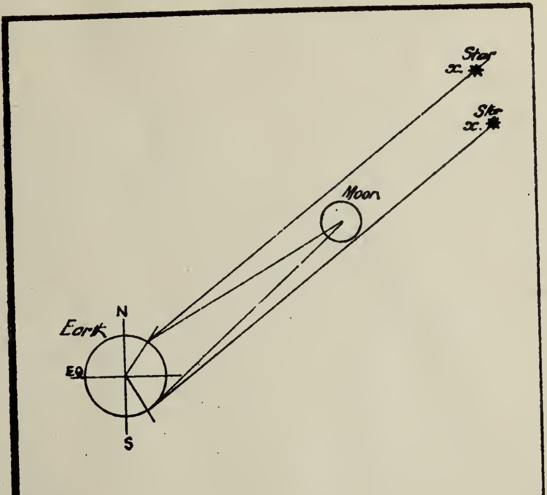


12 CORONA BOREALIS, the N. crown.

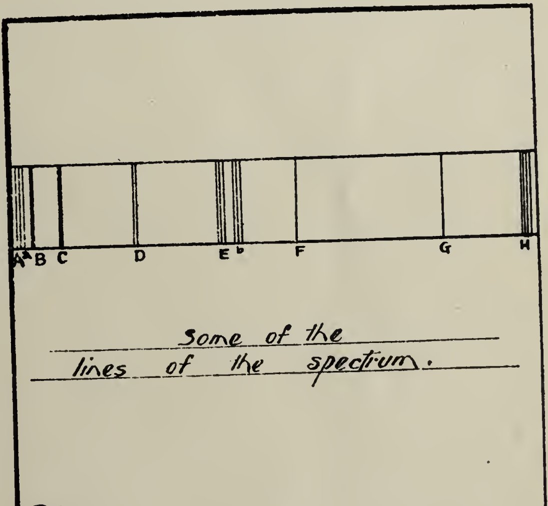

13 DELPHINUS, the dolphin.

14 The Pleiades

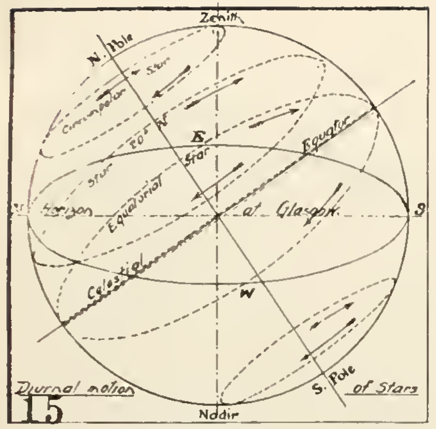

1852
ultiple Star
ta Orionis
Low power
tar image


Star
x.
Star
x.
Moon
N
Earth
EQ
S

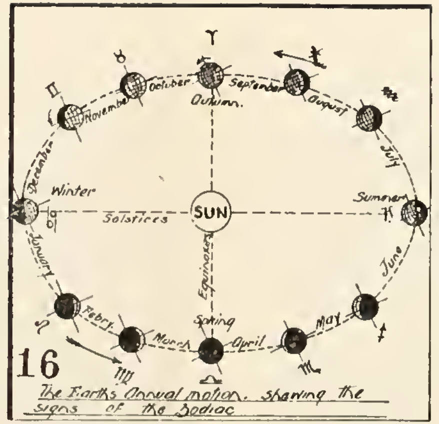
21


A a B C D E b F G H
Some of the
lines of the spectrum.

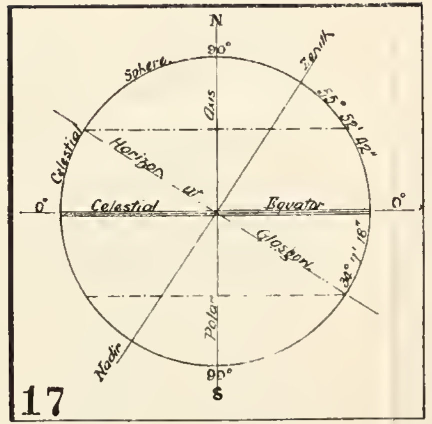
27



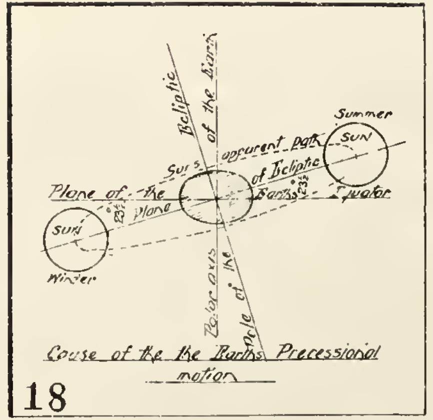
15
Diurnal motion of Stars



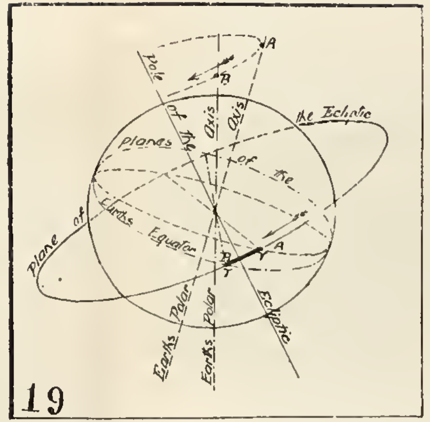
16
The Earths Annual motion, shewing the signs of the Zodiac



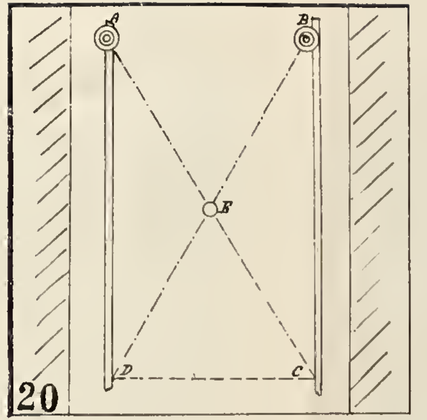
17



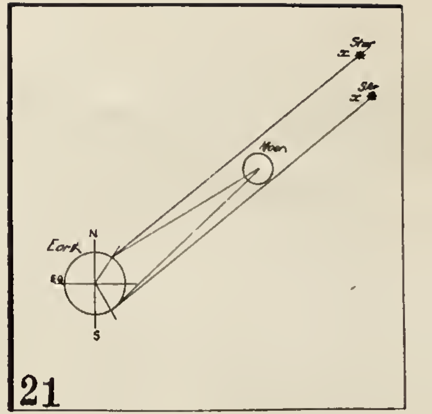
18
Cause of the the Earths Precessional motion



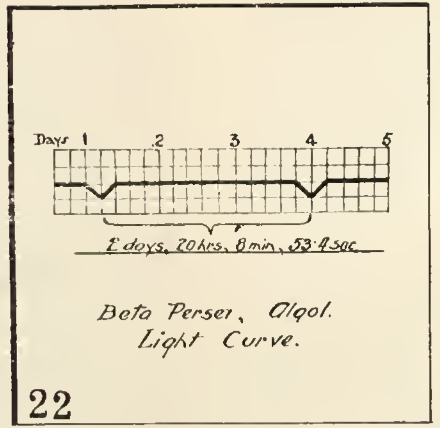
19



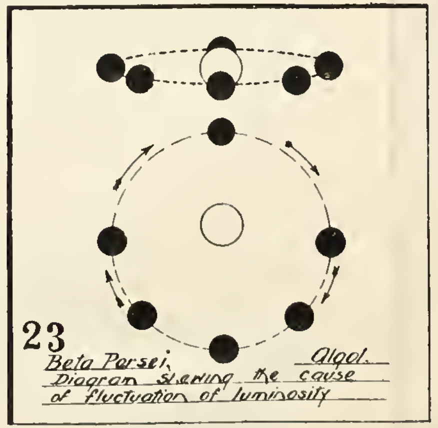
20



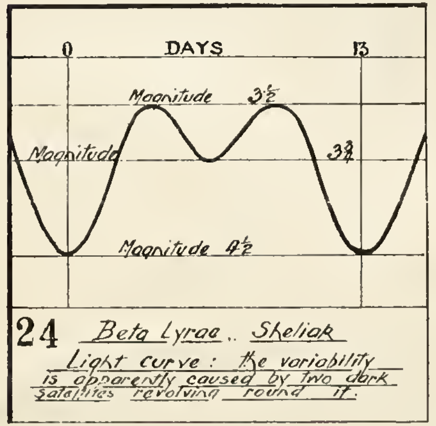
21



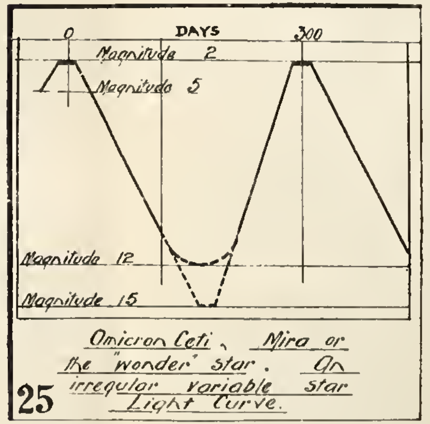
22
Beta Persei, Algol.
Light Curve.



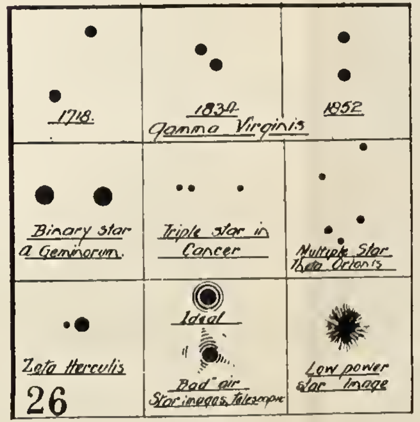
23
Beta Persei, Algol.
Diagram shewing the cause of fluctuation of luminosity



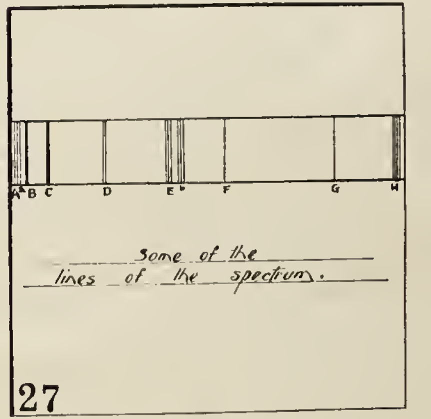
24
Beta Lyrae, Sheliak
Light curve: the variability is apparently caused by two dark satellites revolving round it.



25
Omicron Ceti, Mira or the "wonder" star. An irregular variable star
Light Curve.



26



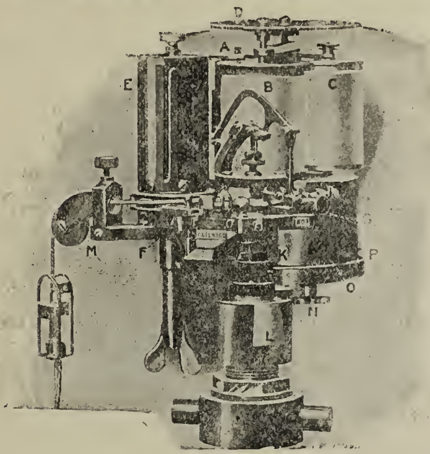
27
Some of the lines of the spectrum.

Beta Aurigæ, 2·1; Beta Trianguli, Fig. 11, 3·1 magnitude, and so on. With regard to the last question, the latitude of a place does not agree with the highest point at which a circumpolar star touches the meridian, as will be seen on referring to Fig. 17. The highest point from the horizon at which a circumpolar star "souths," or culminates at the latitude of Glasgow, which is 55 degrees 52 minutes 42 seconds, is 68 degrees 14 minutes 36 seconds. Possibly Mr Laurence may wish to know by this question how the latitude of any place is found. By observing the pole star at upper and lower culminations, and bisecting the diameter vertically, the point then found is the pole. The angular distance of this point from the zenith is the co-latitude, that quantity subtracted from a right angle gives the latitude, or the distance of the pole star (or, rather, of this point bisecting its circular path vertically) measured from the northern horizon on the meridian is also the latitude.

On the motion of the Chairman, Mr McDougall was accorded a vote of thanks for his paper.

Adopted by the Admiralty, War Office and India Office.

"McINNES-DOBBIE" INDICATORS



For all
STEAM
and
EXPLOSION
ENGINES.

Illustration of our Gas Engine Indicator with "MATHOT" EXPLOSION RECORDER.

DOBBIE McINNES, Ld., 57 BOTHWELL ST. GLASGOW.

You will find the Latest Technical Books

AND NOTHING BUT

Technical and Engineering Books

AT THE FOLLOWING ADDRESS.

Our Stock is specially arranged so that anyone interested may see at one view the current Literature in their branch of the subject or of the whole subject. The Books may be taken down and freely examined; every facility for leisurely inspection is given. Please call or write for Catalogue, which we send Post Free.

N.B.—State Subjects in which you are interested.

JOHN SMITH & SON

(Glasgow) Ltd.,

195 GEORGE STREET

(Opposite the Technical College).

Syllabus of Nineteenth Session, 1910-11.

Meetings will be held in the GLASGOW AND WEST OF SCOTLAND TECHNICAL COLLEGE, George Street, except where otherwise stated, on the following Saturday Evenings, at 7-30 o'clock.

1910.

Oct. 15.—SMOKING CONCERT.
The Grosvenor Restaurant.

Oct. 29.—" Paper Making."
WM. WATSON, Esq.

Nov. 12.—" Modern Lathes and Methods."
ROBERT LANG, Esq., M.I.Mech.E.

Nov. 26.—" The Fixed Stars."
JOHN D. MCDOUGALL, Esq.

Dec. 10.—" Metallography as an Aid to the Engineer."
JOHN S. G. PRIMROSE, Esq., A.G.T.C.

Dec. 17.—ANNUAL DINNER.
The Grosvenor Restaurant.

1911.

Jan 21.—" Experimental Engineering as an Aid to Design."
ROBERT ROYDS, Esq., M.Sc.

Feb. 4.—" Heating and Ventilation of Large Buildings."
A. WHITTAM, Esq.

Feb. 18.—MEMBERS' NIGHT.

Mar. 4.—" Steam in Sugar Refining."
CHARLES FERGUSON, Esq.

Mar. 18.—" Recent Developments in Telegraphy."
THOMAS HETHERINGTON, Esq.

April 1.—ANNUAL GENERAL MEETING.
The Technical College.

AND SMOKING CONCERT.
The Grosvenor Restaurant.

FRASER, ASHER & CO. LTD:
ENGINEERING PRINTERS,
GLASGOW.